Talanta 81 (2010) 510–515

Contents lists available at ScienceDirect

Talanta

journal homepage: www.elsevier.com/locate/talanta

Carbon paste and PVC electrodes for the flow injection potentiometric determination of dextromethorphan

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ARTICLE INFO

Article history:
Received 10 November 2009
Received in revised form
17 December 2009
Accepted 20 December 2009
Available online 28 December 2009

Keywords:
Dextromethorphan
CPEs
PVC electrode
Flow injection analysis
Pharmaceutical preparations
Solubility products

ABSTRACT

The construction and performance characteristics of dextromethorphan (DXM) carbon paste (CPEs) and polyvinyl chloride (PVC) electrodes are described. Different modes for electrode modification, including incorporation of ion pairs (IPs), ion pairing agent or soaking the plain electrode in IPs suspension, have been used. Matrices compositions were optimized referring to the effect of modifier and plasticizer. The fabricated electrodes work satisfactorily in the concentration range from 10^{-5} to 10^{-2} mol L^{-1} with fast response time (1.6 s) and long operational lifetime (2 months). The developed electrodes have been successfully applied for the potentiometric determination of DXM in pharmaceutical formulation under batch and flow injection analysis (FIA) conditions. Under FIA conditions, the proposed electrodes allow the analysis of 90 samples h^{-1} and offer the advantage of simplicity, accuracy and automation feasibility. The solubility products of various DXM-IPs were determined conductometrically.

1. Introduction

Dextromethorphan (DXM, ent-3-methoxy-17-methylmorphinan, $C_{18}H_{25}NO$) is a nonnarcotic antitussive drug, acts through depression of the medullary centers of the brain to decrease the involuntary urge to cough [1]. High performance liquid chromatography (HPLC) [2], gas chromatography [3] and liquid chromatography techniques [4] are the most popular techniques for DXM quantification. Moreover the derivative spectrophotometry [5,6], ion pair complex formation [7,8], proton nuclear magnetic resonance (^{1}H NMR) [9] and capillary electrophoresis (CE) [10] have also been reported.

The widespread dosefication and/or adulteration of commercially available pharmaceutical preparations demands simple, sensitive, selective and rapid methods for drug quality control. Nevertheless, most of the aforementioned methods require expensive apparatus or involve several manipulation steps before the final result of analysis. In contrast, the electrochemical techniques such as potentiometric measurements possess analytical and economic advantages including simple instrumentation, high sensitivity, fast response and possible interfacing with FIA systems. Although ion-selective electrodes (ISEs) had found wide applications for drug quality control [11–13], only a DXM-PVC electrode has recently been found in the literature [14]. The proposed electrode showed a useful working range from 5×10^{-5} to 10^{-3} mol L^{-1} and dynamic response time of 10 s.

PVC electrodes still have certain inherent limitations as they are mechanically complicated, difficulty of miniaturization and have short lifetime due to the leaching out of the electroactive material [15]. The constant development of ISEs has led to sensors not only that have better performance but also of simpler and more reliable construction. To overcome the aforementioned PVC limitations, CPEs have been developed and introduced as an alternative, possessing the advantages of long operational lifetime, short response time, low Ohmic resistance and easer fabrication and regeneration process. Although a considerable attention has been given to the preparation of CPEs, their applications have been focused on preconcentration followed by voltammetric determination of the analyte [16,17] and just few of these electrodes have been used as potentiometric sensors [18–21].

FIA becomes a wide spread methodology characterized by versatility, ease of automation and high sampling frequency. It is viewed as a well efficient mean of improving the performance characteristics of ISEs [22–25]. The action of the flowing stream continuously cleans the electrode surface and the transient nature of the signal may help to overcome the effect of interfering ions.

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0039-9140/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.talanta.2009.12.033

The present study is concerned with preparation, characterization and application of simple potentiometric sensors for rapid determination of DXM in pure and dosage forms. Both CPEs and PVC electrodes were fabricated in plain and modified forms and subjected to a series of tests to elect sensor possessing the most favorable analytical characteristics. The developed sensors were applied in the potentiometric determination of DXM under FIA system as well as in batch analysis using standard addition and potentiometric titration.

2. Experimental

2.1. Reagents

All reagents were of the analytical grade and bidistilled water was used throughout the experiments. o-Nitrophenyloctylether (o-NPOE, Sigma, 73732), dibutylphthalate (DBP, BDH, 28073), dioctylphthalate (DOP, Sigma, 6699), dioctylsebacate (DOS, Avocado, 122-62-3) and tricresylphosphate (TCP, Fluka, 1330-78-5) were used as electrode plasticizer. PVC (relative high molecular weight, Aldrich, 389293) and graphite powder (synthetic 1–2 μm, Aldrich, 28, 286-3) were applied in electrode fabrication.

Ion pairing agents such as sodium tetraphenylborate (NaTPB, Fluka, 143-66-8), silicotungstic acid (STA, Fluka, 12027-38-2), phosphotungstic acid (PTA, Fluka, 12501-23-4), phosphomolybdic acid (PMA, Fluka, 51429-74-4) and reineckate ammonium salt (RAS, Fluka, 13573-16-5) were used for precipitation of different DXM-IPs.

2.2. Authentic samples

Authentic dextromethorphan HBr monohydrate sample ($C_{18}H_{26}BrNO{\cdot}H_2O$ assigned to be 99%) was kindly provided from National Organization of Drug Control and Research, Giza, Egypt. Stock drug solution (10^{-2} mol L^{-1}) was prepared by dissolving the appropriate amount of DXM in bidistilled water and kept at 4 °C.

2.3. Pharmaceutical preparations

Tussilar tablets and drops (Kahira Pharm. and Chem. Ind. Co., Cairo, Egypt, 10 mg/tablet and 1 g/100 mL solution, respectively) were purchased from local drug stores. Ten tablets were weighed, grinded and an accurate weight of the powder assigned to contain 100 mg DXM was dissolved in bidistilled water, filtered and completed to 50 mL with bidistilled water.

2.4. Apparatus

Potential measurements were carried out using a 692-pH meter (Metrohm, Herisau, Switzerland, Art.no. 1.691.00100) with Ag/AgCl double-junction reference electrode (Metrohm, Art.no. 6.0726.100) and a combined pH glass electrode (Metrohm, Art.no. 6.0202.100). Conductivities were measured using Jenway 4310 conductometer. Water distiller of Hamilton Laboratory Glass Ltd., WSC/4D (UK) was used for bidistilled water preparation. Elemental analysis was carried out on the apparatus Elementar, Vario EL (Germany).

A schematic diagram of the single line flow injection manifold is shown in Fig. 1 which was composed of four channel peristaltic pump (MCP Ismatec, Zurich, Switzerland) and sample injection valve (ECOM, Ventil C, Czech Republic) with exchangeable sample loops (5–500 μL). Solutions transferring were Tygon tubes (Cole-Parmer, USA, 95609-48, 2.8 mm i.d.). A home-made Perspex wall-jet cell was used in the flow measurements, providing a low dead volume, fast response, good wash characteristics, ease of construction, and compatibility with different electrodes.

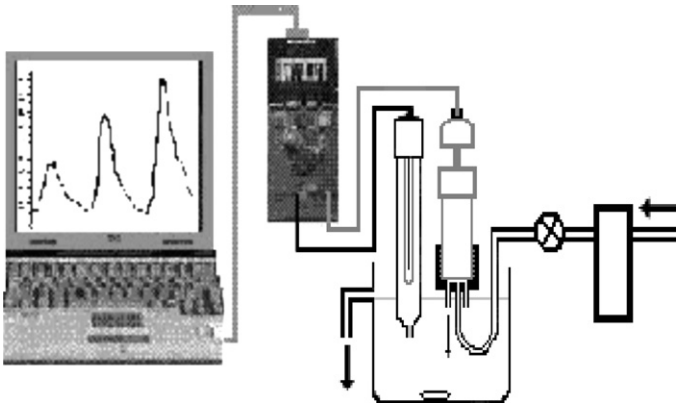

Fig. 1. Manifold of single channel FIA set up used for DXM determination.

The change in electrode potential was monitored using 46-Range Digital Multimeter (Radioshack, China) with PC interface.

2.5. Procedures

2.5.1. Ion pairs preparation

Different DXM-IPs were precipitated by dropwise addition of the ion pairing solution to 50 mL of 10^{-2} mol L^{-1} DXM solution with continuous stirring for 10 min. The precipitated IPs were then filtered off, washed several times with water and dried at 50 °C. The chemical compositions of the different ion pairs (IPs) were confirmed by elemental analysis and conductometric titration.

2.5.2. Sensor construction

Matrices compositions for both the CPEs and PVC electrodes are given in Table 1 following the procedures described elsewhere [20,21]. For PVC electrodes, the internal filling solution was 10^{-3} mol L^{-1} DXM and 10^{-2} mol L^{-1} KCl and Ag/AgCl reference electrode (Metrohm, Art.no. 6.0726.100) was used. The fabricated electrodes were conditioned in 10^{-3} mol L^{-1} DXM before use. Plain electrode was prepared in the same manner using the plain PVC membranes and presoaked in freshly prepared ion pair suspensions for 24 h.

Carbon paste electrodes were prepared by hand mixing graphite powder, plasticizer and modifier using an agate mortar where the paste mixture was packed into a piston driven Teflon holder [17]. The fabricated CPEs were conditioned in 10^{-3} mol L^{-1} DXM solution for 24 h. Plain CPEs were prepared without incorporation of modifier and soaked in freshly prepared ion pair suspensions.

2.5.3. Calibration of sensors

For batch measurements, sensors were calibrated by transferring 25 mL aliquots of 10^{-6} to 10^{-2} mol L^{-1} DXM solutions into a 50 mL double jacket thermostated glass cell at 25 °C followed by immersing the sensor in conjugation with reference electrode in the measuring solution. The potential readings were recorded and plotted against drug concentration in logarithmic scale (log [DXM]).

For FIA measurements, 200 μL of freshly prepared DXM solutions covering the range 10^{-6} to 10^{-2} mol L^{-1}, was injected in the flowing stream (45 mL min^{-1}) and the corresponding peak heights were recorded and used to draw the calibration graphs.

2.5.4. Potentiometric determination of DXM in pharmaceutical preparations

DXM was potentiometrically determined in pure solution and pharmaceutical preparations using the developed electrodes under both batch conditions (by standard addition and potentiometric titration) and FIA conditions. In standard addition method, known

Table 1
Optimal matrix compositions of the different DXM sensors prepared with different modes.

Sensor	Mode	Matrix composition
CPE	Modified with IP	25 mg DXM-TPB + 250 mg carbon powder + 100 μL *o*-NPOE
	Modified with ion pairing agent	30 mg NaTPB + 250 mg carbon powder + 100 μL *o*-NPOE
	Plain	250 mg carbon powder + 100 μL *o*-NPOE
PVC	Modified with IP	15 mg DXM-TPB + 240 mg *o*-NPOE + 6 mL THF + 240 mg PVC
	Modified with ion pairing agent	10 mg NaTPB + 240 mg *o*-NPOE + 6 mL THF + 240 mg PVC
	Plain	240 mg *o*-NPOE + 6 mL THF + 240 mg PVC

increments of 10^{-2} mol L^{-1} standard DXM solution were added to 25 mL aliquot of sample solution where the change in the potential readings was recorded for each increment and used to calculate the concentration of DXM in sample solution.

For potentiometric titration, aliquots of the sample solutions containing 0.27–13.5 mg DXM were titrated against standard NaTPB solution. The titration process was monitored using DXM sensor in conjugation with the conventional Ag/AgCl reference electrode and the potential values were plotted against the titrant volume to estimate the end point.

Under FIA conditions, 200 μL of sample solutions were injected where the peak heights were measured at the optimum conditions and compared to those obtained from injecting standard solutions of the same concentration.

3. Results and discussion

3.1. Ion pair identification studies

DXM is a tertiary amine cation which forms water insoluble ion pair complexes with NaTPB, RAS, PTA, STA and PMA, the resultant ion pairs (IPs) could be used as ion exchangers in DXM sensors construction. From this point of view, different types of DXM-IPs were prepared and their stoichiometric ratios were estimated from elemental analysis and conductometric titration data [26,27]. DXM forms 1:1 (reagent:drug) IPs with both TPB and RAS, while PTA and PMA showed ratio 1:3, STA formed complex of 1:4. The solubility products were found to be 3.48×10^{-9}, 1.92×10^{-9}, 9.90×10^{-20}, 2.15×10^{-18}, and 2.28×10^{-22} for DXM-TPB, DXM-RAS, DXM-PMA, DXM-PTA and DXM-STA ion-pairs, respectively, indicating the low solubility of these IPs.

3.2. Optimization of the electrode performance under batch condition

For quantitative and qualitative composition optimization of the developed CPEs and PVC sensors, an election scheme was followed. Both unmodified (plain) and modified electrodes (with IPs or ion pairing agents) were prepared and tested for the effect of nature and content of modifier, plasticizer, pH, response time, sensitivity and applications.

3.2.1. Electrodes modified with DXM ion pairs

Both CPE and PVC modified in bulk with different DXM-IPs as electroactive components were prepared and conditioned in 10^{-3} mol L^{-1} of DXM solution for 24 h. Preliminary experiment declared that both the CPE and PVC electrodes that contain no electroactive material and plasticized with o-NPOE showed no response towards the DXM while those modified with different DXM-IPs gave Nernstian responses towards DXM with different slope values depending on the IP used.

The incorporation of DXM-TPB showed the best performance (slope 51.7 ± 0.7 and 52.6 ± 0.9 mV/decade for CPE and PVC, respectively) compared with other DXM IPs modified electrodes. This behavior may be attributed to the low solubility of these IPs in the electrode matrix. The influence of the DXM-TPB content (5–30 mg) in the electrode matrix, for both the CPE and PVC, was also investigated. For PVC electrode, addition of 15 mg gave the best performance (slope 56.4 ± 0.7 mV/decade); the slope of the electrode decreased to reach 48.0 mV/decade at 30 mg IP. For CPE, incorporation of 25 mg of the DXM-TPB was selected giving a Nernstian slope of 55.7 ± 0.9 mV/decade.

3.2.2. Electrode modified with the ion pairing agents

Incorporation of a suitable ion pairing agent in the electrode matrix followed by soaking in the drug solution has led to the formation of an ion exchanger at the electrode surface which subsequently extracted by the plasticizer into the electrode bulk. Such technique will reduce the time required for the electrode fabrication, as there is no need for IP precipitation [20,21].

The effect of the ion pairing agent type was tested by incorporation of different ion pairing agents in the electrode matrices. The obtained results indicated the superiority of NaTPB incorporation in the electrode matrix as indicated by the highest slope value (59.5 and 58.5 mV/decade for PVC and CPE, respectively). The content of NaTPB was varied from 5 to 50 mg and it was found that addition of 10 and 30 mg of NaTPB in the electrodes matrices gave the highest slope values of 63.2 ± 0.8 and 61 ± 1.6 mV/decade for PVC and CPE, respectively.

3.2.3. Plain electrodes

In addition to the aforementioned methods for electrode fabrication, a simple and reliable suggested procedure could be applied by soaking the plain electrodes in the aqueous suspension of the lipophilic IP where the electrode mediator (plasticizer) extracts IP and becomes gradually saturated with this IP. There is no need to add neither IP nor the ion pairing agent into the electrode matrix during its fabrication. The IP concentration in the electrode phase increases with increasing both the extractability and the solubility product of the IP formed [28].

The plain electrodes were soaked in the aqueous suspensions of different DXM-IPs for 24 h and used for potentiometric measurements. Results showed that, the electrodes soaked in the DXM-TPB possessed the best sensitivity indicated by the highest slopes compared with other ion pairs (54 ± 0.3, 48.5 ± 3.1, 40 ± 0.9, 44.7 ± 2.6 and 42.5 ± 4.3 mV/decade for PVC soaked in DXM-TPB, DXM-RAS, DXM-PTA, DXM-PMA and DXM-STA, respectively) which is directly related to the solubility products of these IPs. For carbon paste electrodes, soaking in DXM-TPB also gave the best performance as indicated by Nernstian slope 57.7 ± 0.5 mV/decade.

3.2.4. Effect of the plasticizer

Plasticizers play an important role in the behavior of the ISEs, since they improve the solubility of the sensing materials and lower the overall electrode bulk resistance due to their polarity characteristics. The plasticizer influence on the electrode performance has been studied. The electrode plasticized with o-NPOE was compared with those plasticized with TCP, DOS, DBS, DOP and DBP. The obtained calibration graphs using different plasticizers clarified that o-NPOE plasticized electrode showed the highest sensitivity

Table 2
Performance characteristics[a] of DXM sensors fabricated with different techniques.

	PVC			CPE		
	Modified with DXM-TPB	Modified with NaTPB	Plain	Modified with DXM-TPB	Modified with NaTPB	Plain
Concentration range (mol L^{-1})	10^{-5}–10^{-2}	10^{-5}–10^{-2}	10^{-5}–10^{-2}	10^{-5}–10^{-2}	10^{-5}–10^{-2}	10^{-5}–10^{-2}
Intercept (mV)	307.1 ± 3.3	344.7 ± 2.8	283.5 ± 1.2	497.7 ±2.4	526.0 ±5.2	536.7 ± 3.3
Slope (mV dec^{-1})	56.4 ± 0.7	63.2 ± 0.8	54.0 ± 0.3	55.7 ± 0.9	61 ± 1.6	57.7 ± 0.5
R	0.9997	0.9999	0.9999	0.9998	0.9994	0.9998
LOD (mol L^{-1})	7.9×10^{-6}	10^{-5}	8.3×10^{-6}	10^{-5}	10^{-5}	10^{-5}
Response time (s)	5	10	8	1.6	3	2
Lifetime (day)	28	21	14	60	40	30
Working pH range	3–8			3–7		

[a] Average of five calibration graphs.

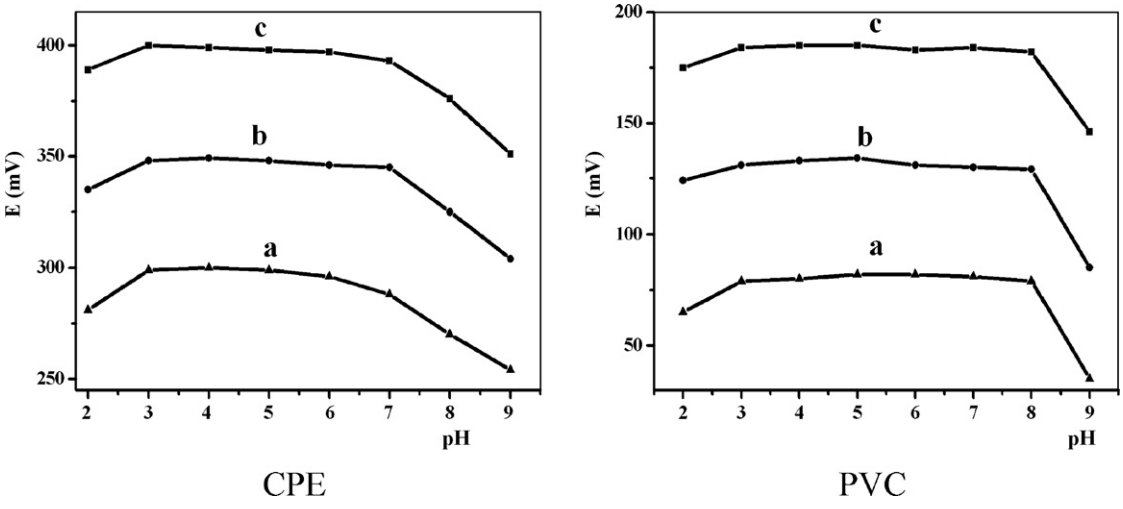

Fig. 2. Effect of the pH on the potential readings of both PVC and CPE electrodes: (a) 1×10^{-4}, (b) 1×10^{-3}, and (c) 1×10^{-2} mol L^{-1} DXM.

indicated by the highest slope (63.2 ± 0.8, 50.9 ± 4.6, 50.5 ± 2.0, 49.7 ± 6.2, 47.5±2.2 and 44.6 ± 6.0 mV/decade for o-NPOE, TCP, DOS, DBS, DOP and DBP, respectively) which may be related to the dielectric constant of these plasticizers (ε = 24, 17.6, 3.8, 4.5, 5.2 and 4.7 for the tested plasticizers, respectively).

3.3. Sensors performance

The potentiometric response characteristics of both CPE and PVC sensors were evaluated according to IUPAC recommendations [29]. Data obtained (Table 2) indicated that the developed sensors can be successfully applied for the potentiometric determination of DXM in the concentration range from 10^{-5} to 10^{-2} mol L^{-1} with Nernstian cationic slopes depending on the type of the electrode and method of fabrication. The limit of detection was found to be ranged from 7.9×10^{-6} to 10^{-5} mol L^{-1}.

For analytical applications, the response time of a new fabricated sensor is of critical importance. CPEs showed fast and stable potential readings as the response time was about 1.6 s only. For PVC electrode, the electrode modified with DXM-TPB showed faster response time (5 s) than other types of PVC electrodes (about 8 s).

The lifetime of the different fabricated electrodes was tested by performing day-to-day calibration. PVC electrodes showed useful lifetime of 14–28 days during which the Nernstian slopes did not change significantly (±2 mV/decade), while the detection limit was shifted from 10^{-5} to 10^{-4} mol $^{-1}$ DXM at the end of this period. The relatively short lifetime of the electrode may be related to the leaching of the sensing material into both internal reference solution and external bathing solution. CPEs showed a relatively longer working lifetime (30–60 day) which may be attributed to the diminishing of the IP leaching from the electrode matrix due to absence of the internal reference solution.

The influence of pH on the response of both PVC and CPE was studied by recording the electrode potential readings at different pH values (pH 2–9, Fig. 2). The electrodes responses were found to be pH independent in the range 3.0–8.0 and 3.0–7.0 for PVC and CPEs, respectively.

The selectivity of the prepared DXM sensors was tested towards different species (Table 3) using Matched Potential Method (MPM) as recommended by IUPAC [30]. Results revealed a high selectivity toward DXM in the presence of other interferents, additives and fillers commonly introduced in pharmaceutical formulations (such as glycine, caffeine, citrate, maltose, sucrose, and starch) as well as

Table 3
Selectivity coefficient for DXM sensors under batch and FIA conditions.

Interferent	$-\log K_{A,B}$		
	PVC	CPE	
		Batch	FIA
Na^+	2.87	3.10	3.45
K^+	2.79	2.95	3.32
Li^+	3.05	3.30	3.61
NH_4^+	3.31	3.19	3.56
Ca^{2+}	3.51	3.61	3.93
Mg^{2+}	3.45	3.56	3.81
Starch	3.53	3.17	
Maltose	2.92	3.16	
Sucrose	2.71	3.10	
Citrate	2.83	2.69	
Caffeine	2.75	3.18	
Glycine	2.62	2.66	

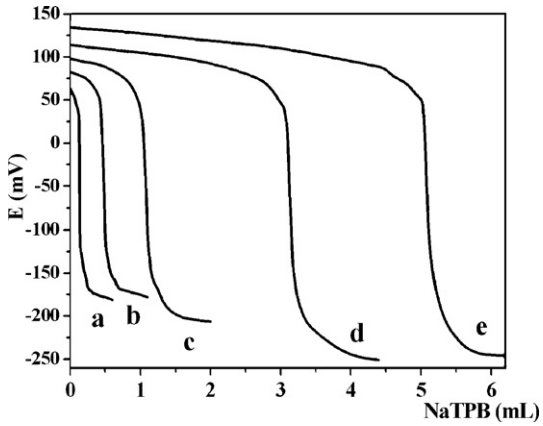

Fig. 3. Potentiometric titration of DXM with 10^{-2} mol L^{-1} NaTPB: (a) 0.27, (b) 1.35, (c) 2.7, (d) 8.1, and (e) 13.5 mg DXM.

inorganic cations, Na^+, K^+, Li^+, Ca^{2+}, Mg^{2+}, and NH_4^+ have no effect on the electrode potential.

3.4. Potentiometric titration

In contrast to direct potentiometric measurements requiring careful calibrations of measuring cells, the potentiometric titration techniques offer the advantage of high accuracy and precision; although the cost of increased time and consumption of reagents used as titrants. The effect of the electrode plasticizer on the titration performance was investigated and it was found that the electrodes plasticized with o-NPOE gave the highest total potential change (ΔE = 250 mV) compared with those plasticized with TCP, DOP, DOS, DBS or DBP (ΔE were 190, 150, 100, 171 and 70 mV for the plasticizers in the same order).

Under the optimum conditions, the titration curves were symmetrical (Fig. 3) with well-defined potential jumps indicating the high sensitivity of the electrode. Concerning the titration process, the total potential changes were large (ΔE = 230–336 mV) allowing the determination of 0.27 mg DXM with mean recovery of 100.22 ± 0.95%.

3.5. Electrode response under FIA conditions

Incorporation of ISEs in flow injection systems has the advantages of automation with high sampling frequency. A home-made Perspex wall-jet cell was used, providing low dead volume, fast response, good wash characteristics, ease of construction and compatibility with electrodes of various shapes and sizes (Fig. 1). An internal screw controls the distance between nozzle and the electrode surface to provide the minimum thickness of the diffusion layer and consequently fast electrode response.

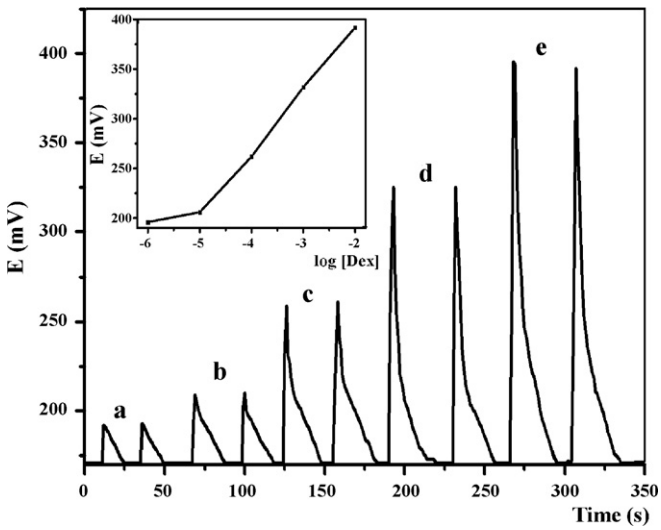

Fig. 4. Flow injection potentiometric determination of dextromethorphan using CPEs: (a) 1×10^{-6}, (b) 1×10^{-5}, (c) 1×10^{-4}, (d) 1×10^{-3}, and (e) 1×10^{-2} mol L^{-1} DXM.

The influence of the sample volume was investigated by injecting 50–500 μL of 10^{-2} mol L^{-1} DXM solution into the carrier stream. It was observed that, the larger the sample volume, the higher the peak height and the longer the residence time of the sample at the electrode surface. A sample loop of 200 μL was used through out this work giving the maximum peak height and suitable residence time. In addition, the dependence of the peak heights and the time to reach the base line on the flow rate was studied by monitoring the sensor responses at different flow rates (15.0–90.0 mL min^{-1}). It was found that, at a fixed injected volume, both the residence time and the peak height were inversely proportional to the flow rate and the flow rate of 45.0 mL min^{-1} was chosen for further investigations to compromise between the peak height and analysis time.

Incorporation of PVC electrode in the flow system was unsatisfactory due to damage of the sensing membrane during electrode holding in the cell or operation at high flow rate. Contrary, incorporation of CPE in the FIA system was much easier due to the solid nature of the electrode and absence of the PVC membrane. CPEs showed a fast response time and stable potential readings as the residence time was only 30 s compared with 70 s for PVC electrode. The dispersion coefficient was 1.18, indicating a limited dispersion that aids to reach the optimum sensitivity and fast response of the sensor.

Fig. 4 showed peaks from the proposed electrode system when 200 μL of DXM solutions at various concentrations were injected in the flowing stream (45 mL min^{-1}). The calibration graph was linear in the concentration range from 10^{-5} to 10^{-2} mol L^{-1} with

Table 4
Determination of DXM in pure form and in pharmaceutical preparations.

Sample	Taken (mg)	Found							
		Official method		Developed sensors					
				Standard addition		Titration		FIA	
		Recovery %	R.S.D.[a]	Recovery %	R.S.D.	Recovery %	R.S.D.	Recovery %	R.S.D.
Pure DXM	0.27	96.52	3.4	98.48	2.5	98.52	1.9	99.52	1.10
	1.89	99.65	2.5	101.20	1.8	98.09	1.46	98.52	1.20
	8.14	99.50	2.2	102.56	2.6	100.22	0.95		
Tussilar tablets	1.89	94.30	1.8	96.54	3.5	102.87	1.31	100.35	0.95
Tussilar drops	1.89	98.56	1.65	103.6	2.1	99.84	1.60	102.35	1.10
	8.14	101.52	1.45	96.73	1.8	104.66	1.75		

[a] Mean recovery and standard deviations for five determinations.

Nernstian slopes of 62.8 ± 1.8 and 67.5 ± 2.8 mV/decade and sampling output of 90 and 40 sample h^{-1} for CPE and PVC, respectively. Reproducibility was evaluated from repeated 10 injections of 200 μL of 10^{-2} mol L^{-1} DXM solution and the average peak heights were found to be 392.1 ± 2.15 mV.

In FIA measurements, where the sample remains in contact with the electrode for a short period of time, the apparent selectivity is expected to be different from that found in batch conditions (Table 3). Under FIA conditions, the values of selectivity coefficients were calculated based on potential values corresponding to the peak heights for the same concentrations of the drug and the interferents according to the separate solution method (SSM). The determined selectivity coefficients of the electrode reflect the high selectivity of the investigated electrode for DXM under both FIA and batch conditions.

3.6. Analytical applications

The proposed electrodes were successfully employed for the assay of DXM in their authentic samples as well as pharmaceutical formulations applying standard addition, FIA and potentiometric titration methods. The results (Table 4) clearly indicated satisfactory agreement between the DXM contents in different samples determined by the developed sensor and official method. The time required for sample analysis time was short in case of FIA (about 1 min) compared with about 10 min for the standard and potentiometric titration methods.

4. Conclusion

The present work demonstrates the fabrication of novel dextromethorphan CPE and PVC electrodes utilizing different preparation methods. The proposed electrodes showed Nernstian slopes in the concentration range 10^{-5} to 10^{-2} mol L^{-1} with fast response time (1.6 s) and long operational lifetime. The fabricated electrodes were successfully applied for the potentiometric determination of DXM in pure and pharmaceutical forms under batch, FIA and potentiometric titration conditions with average recoveries comparable to the official methods. FIA allows high sampling output with the possibility for incorporation in routine analysis for drug quality control.

Acknowledgement

Authors acknowledge the support from the bilateral project 8030501 NRC.

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